RAA 2014 Vol. **14** No. **10**, 1264–1268 doi: 10.1088/1674–4527/14/10/005
http://www.raa-journal.org *http://www.iop.org/journals/raa*

***R**esearch in*
***A**stronomy and*
***A**strophysics*

A long-term *UBVRI* photometric study of the pre-main sequence star V350 Cep

Sunay Ibryamov, Evgeni Semkov and Stoyanka Peneva

Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences, 72 Tsarigradsko Shose Blvd., 1784 Sofia, Bulgaria; *sibryamov@astro.bas.bg*

Received 2014 March 12; accepted 2014 April 23

Abstract Results from *UBVRI* optical photometric observations of the pre-main sequence star V350 Cep during the period 2004−2014 are presented. The star was discovered in 1977 due to its remarkable increase in brightness by more than 5 mag (R). In previous studies, V350 Cep was considered to be a potential FUor or EXor eruptive variable. Our data suggest that during the period of observations the star maintains its maximum brightness with low amplitude photometric variations. Our conclusion is that V350 Cep was probably an intermediate object between FUors and EXors, similar to V1647 Ori.

Key words: stars: pre-main sequence — stars: variable: T Tauri — stars: individual (V350 Cep)

1 INTRODUCTION

Studies of pre-main sequence (PMS) stars are very important for modern astronomy because they give an opportunity to understand the early stages of stellar evolution, as well as to test stellar evolution scenarios. Depending on their initial mass, young stars pass through different periods of stellar activity. The most prominent manifestations of this activity are changes in the star's brightness with various periods and amplitudes.

Photometric and spectroscopic variabilities are the most common characteristics of PMS stars. The most widely-spread type of PMS objects – T Tauri stars are young, low mass stars ($M \leq 2\ M_{\odot}$). Their study began after the pioneering work of Joy (1945). The main characteristics of T Tauri stars are their emission spectra and their irregular photometric variability. Some T Tauri stars exhibit strong brightness variations over comparatively short time intervals (days, months) with amplitudes of up to several magnitudes. T Tauri stars are separated in two subclasses: classical T Tauri stars (CTTS) surrounded by massive accreting circumstellar disks and weak-line T Tauri stars (WTTS) without evidence for disk accretion (Bertout 1989). According to Herbst et al. (1994) photometric variability of WTTS is due to the rotation of the stellar surface covered with large cool spots. The periods of variability in WTTS are observed on time scales of days and with amplitudes up to 0.8 mag in the V-band. Variability of CTTS is more complicated: the variability is caused by a superposition of cool and hot surface spots producing non-periodic variations with amplitudes up to 2–3 mag in the V-band.

The large amplitude outbursts of PMS stars can be grouped into two main types, named after their respective prototypes: FU Orionis (FUor; Ambartsumyan 1971) and EX Lupi (EXor; Herbig

1989). Both types of stars are probably related to low-mass T Tauri stars with massive circumstellar disks, and their outbursts are generally attributed to a sizable increase in accretion rate from the circumstellar disk onto the stellar surface. The outbursts of FUor objects last for several decades, and the rise time is shorter than the decline. EXor objects show frequent (every few years or a decade), irregular or relatively brief (a few months to one year) outbursts with an amplitude of several magnitudes ($\Delta V \approx 3 - 5$).

The PMS star V350 Cep is located in the field of the reflection nebula NGC 7129, a region with active star formation. The region is immersed in a very active and complex molecular cloud (Hartigan & Lada 1985; Miranda et al. 1993). The distance to NGC 7129 as determined by Straižys et al. (2014) is 1.15 kpc.

Variability in V350 Cep was discovered by Gyul'Budagyan & Sarkisyan (1977) who compared their photographic observations of NGC 7129 with the Palomar Observatory Sky Survey (POSS) plates. V350 Cep was not seen on the POSS O-plate obtained in 1954 (limit $\sim$ 21 mag) and is slightly above the limit of the E-plate. The measured brightness of the star in 1977 was approximately 17.5 mag in the B-band and 16.5 mag in the V-band. Follow-up observations by the Sternberg Astronomical Institute (Pogosyants 1991), Sonneberg and Alma-Ata Observatories, which are in plate archives (Gyul'Budagyan 1980), suggest that V350 Cep was below the plate limits before 1970, i.e. it was fainter than 17.5 mag in the B-band. The spectral class of V350 Cep is defined as M2 by Cohen & Fuller (1985) and as M0 by Kun et al. (2009).

Photometric observations of V350 Cep (Gyul'Budagyan & Sarkisyan 1978; Hakverdian & Gyulbudaghian 1978; Shevchenko & Yakubov 1989; Pogosyants 1991; Semkov 1993, 1996, 1997, 2002, 2004a; Semkov et al. 1999) demonstrated changes in brightness, which are typical for CTTS with an amplitude of about 1.5 mag in the B-band. All spectral observations of V350 Cep (Gyulbudaghian et al. 1978; Magakyan & Amirkhanyan 1979; Cohen & Fuller 1985; Goodrich 1986; Miranda et al. 1994; Magakian et al. 1999; Semkov 2004b; Kun et al. 2009) suggest that its spectrum is similar to the CTTS spectra, including being quite variable, having an emission spectrum and a variable P Cygni profile for the Hα line. Collected photometric data indicate that the rise in brightness began some time before 1970, and the light curve of the star resembles that of a classic FUor star V1515 Cyg (see Clarke et al. 2005).

Section 2 gives information about telescopes and cameras used and data reduction. Section 3 describes the derived results and their interpretation.

2 OBSERVATIONS

The CCD observations of V350 Cep were performed in two observatories with four telescopes: the 2-m Ritchey-Chretien-Coude (RCC), the 50/70-cm Schmidt and the 60-cm Cassegrain telescopes of the Rozhen National Astronomical Observatory (Bulgaria) and the 1.3-m Ritchey-Chretien (RC) telescope of the Skinakas Observatory[1] of the University of Crete (Greece).

The observations were performed with seven types of CCD cameras: VersArray 1300B (1340 $\times$ 1300 pixels, 20 $\times$ 20 μm pixel^{-1} size) at the 2-m RCC telescope, Photometrics CH360 (1024 $\times$ 1024 pixels, 24 $\times$ 24 μm pixel^{-1} size) and ANDOR DZ436-BV (2048 $\times$ 2048 pixels, 13.5 $\times$ 13.5 μm pixel^{-1} size) at the 1.3-m RC telescope, SBIG ST-8 (1530$\times$1020 pixels, 9$\times$9 μm pixel^{-1} size), SBIG STL-11000M (4008 $\times$ 2672 pixels, 9 $\times$ 9 μm pixel^{-1} size) and FLI PL16803 (4096 $\times$ 4096 pixels, 9 $\times$ 9 μm pixel^{-1} size) at the 50/70-cm Schmidt telescope, and FLI PL9000 (3056 $\times$ 3056 pixels, 12 $\times$ 12 μm pixel^{-1} size) at the 60-cm Cassegrain telescope. All frames were taken through a standard Johnson-Cousins set of filters. All data were analyzed using the same aperture, which was chosen to have a 6$''$ radius (while the background annulus was taken from 10$''$ to 15$''$). All frames obtained with the VersArray 1300B, Photometrics CH360 and ANDOR DZ436-BV cameras

[1] Skinakas Observatory is a collaborative project of the University of Crete, the Foundation for Research and Technology, Greece, and the Max-Planck-Institut für Extraterrestrische Physik, Germany.

were bias subtracted and flat field corrected. CCD frames obtained with the SBIG ST-8, SBIG STL-11000M, FLI PL16803 and FLI PL9000 cameras were dark-frame subtracted and flat-field corrected. As a reference, the *UBVRI* comparison sequence reported in Semkov (2002) was used.

The results from our photometric observations of V350 Cep are given in Table 1 (see online version). The columns of the table contain the date and Julian date (JD) of the observation, *UBVRI* magnitudes of V350 Cep, telescope and CCD camera used. The mean value of the errors in the reported magnitudes are: 0.01–0.02 mag for I- and the R-band data, 0.02–0.04 mag for the V-band data, 0.02–0.05 mag for the B-band data and 0.04–0.07 mag for the U-band data.

3 RESULTS AND DISCUSSION

The presented photometric data are a continuation of our long-term photometric study of V350 Cep. The *UBVRI* lights curves of V350 Cep from all our CCD observations (Semkov 1996, 1997, 2002, 2004a; Semkov et al. 1999 and the present paper) are shown in Figure 1. In the figure, circles denote CCD photometric data acquired with the 2-m RCC telescope; triangles – the photometric data taken with the 1.3-m RC telescope; diamonds – the photometric data collected with the 50/70-cm Schmidt telescope, and squares – the photometric data obtained with the 60-cm Cassegrain telescope.

The data reported in the present paper indicate that the brightness of V350 Cep remained close to the maximum value during the period 2004−2014 (Table 1). Thus, the star has been keeping its maximum brightness during the past 35 yr and for the same period it showed photometric variability with a low amplitude. The observed amplitudes in the period 1993−2014 are 0.47 mag for the I-band, 0.87 mag for the R-band, 1.19 mag for the V-band, 1.30 mag for the B-band and 0.84 mag for the U-band. These values are typical of T Tauri stars surrounded by an accreting circumstellar disk.

Figure 2 shows the long-term B/pg-light curve of V350 Cep from all available observations. The circles denote our CCD photometric data (Semkov 1996, 1997, 2002, 2004a; Semkov et al. 1999 and the present paper); triangles – the photographic data from the Rozhen Schmidt telescope (Semkov 1993; Semkov 1996); diamonds – the photographic data from Pogosyants (1991); squares – the photographic data from the Asiago Schmidt telescope (Semkov et al. 1999); empty diamonds symbols – the photographic data from Shevchenko & Yakubov (1989); pluses – the photographic data from the Byurakan Schmidt telescope (Gyul'Budagyan & Sarkisyan 1977; Semkov 1993); the empty triangles – the limit of the photographic data from the POSS plates, the Sternberg Astronomical Institute plate archive (Pogosyants 1991) and the Asiago Schmidt telescope plate archive (Semkov et al. 1999). The available photometric data suggest that the period of strong increase in brightness that continued to about 1978 was followed by a period of irregular variability around the level of maximum brightness lasting up to now.

Another important result from our photometric study is the variation of color indices with stellar brightness. The measured color index $V - I$ versus the stellar magnitude V during the period of our CCD observations is plotted in Figure 3. A clear dependence can be seen from the figures: the star becomes redder as it fades. The other indices $V - R$ and $B - V$ show a similar trend on the color-magnitude diagram. Such color variations are typical of T Tauri stars with large cool spots, whose variability is produced by rotation of the spotted surface. Consequently, V350 Cep shows photometric characteristics of WTTS (variability with small amplitude in a time scale of days). On the other hand, the observed spectra of V350 Cep can be classified as a CTTS spectrum (Magakian et al. 1999; Semkov 2004b). As can be seen from Table 1, V350 Cep shows a very strong ultraviolet excess – a characteristic also typical of CTTS. Moreover, the long-term light curve of V350 Cep is similar to FUor type objects such as V1515 Cyg. These discrepancies make V350 Cep a unique object, which is very difficult to classify.

Regardless of its similarity to T Tauri stars, the large amplitude outburst of V350 Cep can only be explained as an episode of enhanced accretion. We suggest that V350 Cep is an object similar to V1647 Ori (see Aspin & Reipurth (2009) and references therein). The eruptive PMS star V1647 Ori

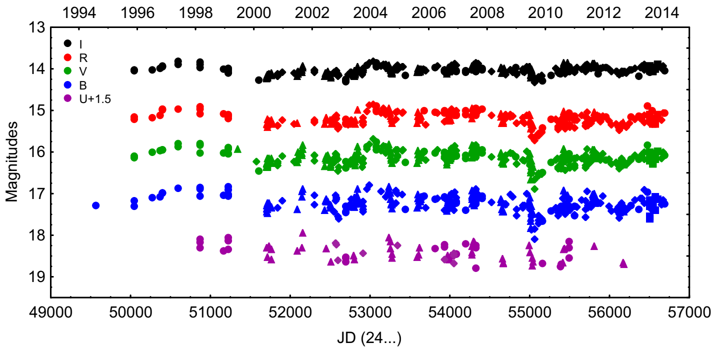

Fig. 1 CCD *UBVRI* light curves of V350 Cep for the period August 1993 – February 2014.

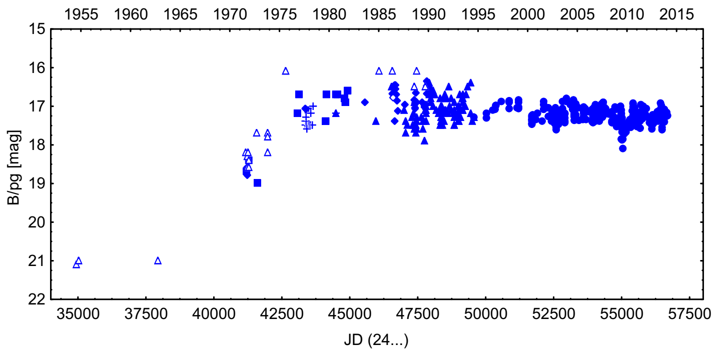

Fig. 2 B/pg light curve of V350 Cep from all available observations.

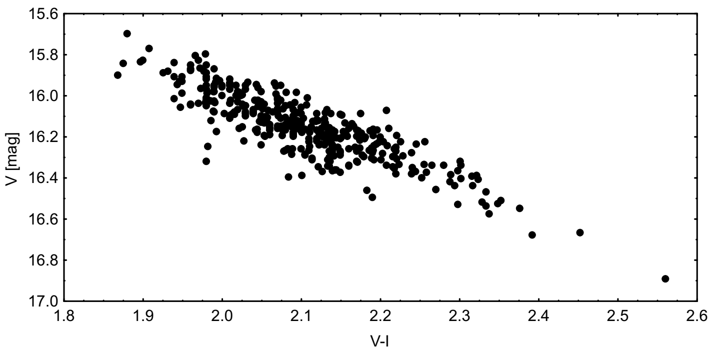

Fig. 3 Relationship between V magnitude and $V-I$ color index in the period of all our CCD observations.

was discovered in 2004 during its large amplitude outburst and is considered to be a unique object which shows photometric characteristics of FUors and spectral characteristics of EXors. Both stars V350 Cep and V1647 Ori show similar photometric and spectral features. These include: a large amplitude outburst continuing several years, random fluctuations in brightness with amplitudes of a few tenths of a magnitude and timescales of several days (García-Alvarez et al. 2011), reddening of the color indices with decreasing brightness, association with reflection nebulae (Miranda et al.

1994), an emission of line spectrum during the maximum light and a variable P Cyg profile for the Hα line.

FUors and EXors have been classified in terms of their wide range of available photometric and spectral properties, but their outbursts are thought to have been caused by an enhanced accretion rate. According to Aspin (2011), the viewing inclination angle of the star/disk system can play a significant role in the observed spectral features, and therefore for the classification of the object as FUor or EXor. It is possible that the two types of eruptive variables FUors and EXors could be much closer in nature.

Acknowledgements This study was partly supported by ESF and the Bulgarian Ministry of Education and Science under the contract BG051PO001-3.3.06-0047. The authors thank the Director of Skinakas Observatory Prof. I. Papamastorakis and Prof. I. Papadakis for award telescope time. The research has made use of the NASA Astrophysics Data System Abstract Service.

References

Ambartsumyan, V. A. 1971, Astrophysics, 7, 331
Aspin, C. 2011, AJ, 142, 135
Aspin, C., & Reipurth, B. 2009, AJ, 138, 1137
Bertout, C. 1989, ARA&A, 27, 351
Clarke, C., Lodato, G., Melnikov, S. Y., & Ibrahimov, M. A. 2005, MNRAS, 361, 942
Cohen, M., & Fuller, G. A. 1985, ApJ, 296, 620
García-Alvarez, D., Wright, N. J., Drake, J. J., et al. 2011, in Astronomical Society of the Pacific Conference Series, 448, 16th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, eds. C. Johns-Krull, M. K. Browning, & A. A. West, 609
Goodrich, R. W. 1986, AJ, 92, 885
Gyulbudaghian, A. L., Glushkov, Y. I., & Denisyuk, E. K. 1978, ApJ, 224, L137
Gyul'Budagyan, A. L. 1980, in Flare Stars, Fuors and Herbig-Haro Objects, ed. L. V. Mirzoyan, 199
Gyul'Budagyan, A. L., & Sarkisyan, R. A. 1977, Astronomicheskij Tsirkulyar, 972, 7
Gyul'Budagyan, A. L., & Sarkisyan, R. A. 1978, Astronomicheskij Tsirkulyar, 982, 4
Hakverdian, L. G., & Gyulbudaghian, A. L. 1978, Astronomicheskij Tsirkulyar, 1027, 3
Hartigan, P., & Lada, C. J. 1985, ApJS, 59, 383
Herbig, G. H. 1989, in European Southern Observatory Conference and Workshop Proceedings, 33, ed. B. Reipurth, 233
Herbst, W., Herbst, D. K., Grossman, E. J., & Weinstein, D. 1994, AJ, 108, 1906
Joy, A. H. 1945, ApJ, 102, 168
Kun, M., Balog, Z., Kenyon, S. J., Mamajek, E. E., & Gutermuth, R. A. 2009, ApJS, 185, 451
Magakyan, T. Y., & Amirkhanyan, A. S. 1979, Astronomicheskij Tsirkulyar, 1038, 6
Magakian, T. Y., Movsesian, T. A., & Hovhannesian, E. R. 1999, Astrophysics, 42, 121
Miranda, L. F., Eiroa, C., & Gomez de Castro, A. I. 1993, A&A, 271, 564
Miranda, L. F., Eiroa, C., Fernandez, M., & Gomez de Castro, A. I. 1994, A&A, 281, 864
Pogosyants, A. Y. 1991, Information Bulletin on Variable Stars, 3624, 1
Semkov, E. H. 1993, Information Bulletin on Variable Stars, 3825, 1
Semkov, E. H. 1996, Information Bulletin on Variable Stars, 4339, 1
Semkov, E. 1997, in IAU Symposium, 182, Herbig-Haro Flows and the Birth of Stars, eds. B. Reipurth, & C. Bertout, 42
Semkov, E. H. 2002, Information Bulletin on Variable Stars, 5214, 1
Semkov, E. H. 2004a, Baltic Astronomy, 13, 538
Semkov, E. H. 2004b, IBVS, 5556, 1
Semkov, E. H., Mutafov, A. S., Munari, U., & Rejkuba, M. 1999, Astronomische Nachrichten, 320, 57
Shevchenko, V. S., & Yakubov, S. D. 1989, Soviet Ast., 33, 370
Straižys, V., Maskoliūnas, M., Boyle, R. P., et al. 2014, MNRAS, 438, 1848

Table 1: Photometric CCD observations of V350 Cep during the period August 2004 - February 2014

Date	JD (24...)	I	R	V	B	U	Telescope	CCD
2004 Aug 11	53228.575	13.98	15.06	15.93	16.98	-	1.3m	Phot
2004 Aug 18	53235.552	13.96	-	15.91	16.94	-	1.3m	Phot
2004 Aug 20	53238.409	13.93	14.96	15.83	16.85	16.57	1.3m	Phot
2004 Aug 22	53239.545	13.97	-	15.95	16.97	-	1.3m	Phot
2004 Aug 23	53240.550	13.97	-	15.91	16.96	-	1.3m	Phot
2004 Aug 23	53241.470	14.00	-	16.00	17.04	-	1.3m	Phot
2004 Sep 08	53257.400	13.99	15.07	15.97	17.00	16.67	1.3m	Phot
2004 Sep 09	53258.329	14.04	15.14	16.08	17.14	16.84	1.3m	Phot
2004 Sep 18	53266.552	14.11	-	16.20	17.25	-	1.3m	Phot
2004 Sep 20	53268.559	14.09	-	16.17	17.28	-	1.3m	Phot
2004 Sep 20	53269.425	14.06	15.21	16.14	17.26	-	1.3m	Phot
2004 Sep 23	53272.470	14.03	-	16.04	17.15	-	1.3m	Phot
2004 Sep 28	53277.305	14.09	15.25	16.18	17.22	16.97	1.3m	Phot
2004 Sep 29	53278.316	14.12	15.31	16.27	17.28	17.06	1.3m	Phot
2004 Sep 30	53279.353	14.13	15.32	16.27	17.37	-	1.3m	Phot
2004 Oct 03	53281.561	14.10	-	16.19	17.25	-	1.3m	Phot
2004 Nov 17	53327.377	14.03	15.22	16.20	17.23	-	Sch	ST-8
2004 Nov 18	53328.321	13.96	15.05	15.97	16.94	-	Sch	ST-8
2004 Nov 20	53330.347	13.97	15.05	15.96	16.98	-	Sch	ST-8
2004 Dec 08	53348.289	14.03	-	16.13	-	-	Sch	ST-8
2004 Dec 09	53349.271	14.01	-	16.08	-	-	Sch	ST-8
2004 Dec 10	53350.243	13.92	15.03	15.95	17.01	16.76	Sch	ST-8
2005 Feb 10	53412.219	13.96	15.07	15.98	17.04	-	Sch	ST-8
2005 Feb 11	53413.212	13.96	15.05	15.96	-	-	Sch	ST-8
2005 Mar 13	53442.596	14.16	-	16.26	17.38	-	2m	VA
2005 Aug 13	53596.417	14.10	15.31	16.27	17.35	17.03	1.3m	Phot
2005 Aug 22	53605.276	13.99	15.05	15.98	17.03	-	1.3m	Phot
2005 Aug 23	53606.279	14.03	15.15	16.07	17.12	-	1.3m	Phot
2005 Aug 26	53609.331	14.06	15.18	16.15	17.19	-	1.3m	Phot
2005 Aug 27	53610.284	14.07	15.22	16.21	17.28	16.98	1.3m	Phot
2005 Aug 29	53611.526	14.09	-	16.21	17.29	-	1.3m	Phot
2005 Sep 14	53628.322	14.02	15.14	16.05	17.12	16.82	1.3m	Phot
2005 Sep 18	53632.461	14.07	15.19	16.15	17.20	-	1.3m	Phot
2005 Sep 19	53633.440	14.08	15.24	16.15	17.18	-	1.3m	Phot
2005 Sep 24	53638.423	14.02	15.14	16.05	17.09	-	1.3m	Phot
2005 Oct 03	53646.521	14.04	-	16.08	17.15	-	1.3m	Phot
2005 Oct 31	53675.393	14.01	-	16.03	-	-	Sch	ST-8
2005 Nov 03	53678.201	14.04	15.02	15.99	17.07	-	2m	VA
2005 Nov 25	53700.199	14.06	15.35	16.21	17.36	-	Sch	ST-8
2006 Mar 28	53822.594	13.97	15.05	16.04	17.14	16.83	2m	VA
2006 Apr 24	53849.597	13.94	15.07	15.95	17.12	-	Sch	ST-8
2006 Jul 19	53936.402	14.03	15.28	16.17	17.41	17.09	Sch	ST-8
2006 Jul 22	53938.555	14.08	-	16.13	-	-	2m	Phot
2006 Jul 23	53939.520	14.07	15.07	16.04	17.09	16.73	2m	Phot
2006 Jul 24	53940.517	14.04	15.02	16.02	17.11	16.79	2m	Phot
2006 Aug 21	53968.510	14.12	-	16.31	17.43	-	1.3m	Phot
2006 Aug 22	53969.509	14.08	-	16.25	17.36	-	1.3m	Phot
2006 Aug 29	53976.527	14.05	-	16.19	17.27	-	1.3m	Phot
2006 Aug 29	53977.490	14.06	-	16.19	17.29	-	1.3m	Phot
2006 Aug 30	53978.483	14.03	15.21	16.12	17.21	16.99	1.3m	Phot
2006 Sep 02	53981.343	14.01	-	16.05	17.12	-	1.3m	Phot
2006 Sep 06	53985.209	14.02	15.18	16.07	17.17		1.3m	Phot
2006 Sep 07	53986.201	13.99	-	16.07	17.16	-	1.3m	Phot
2006 Sep 08	53987.443	13.99	15.13	16.04	17.12	-	1.3m	Phot
2006 Sep 09	53988.470	14.03	-	16.12	17.23	-	1.3m	Phot

Table 1: *continued.*

Date	JD (24...)	I	R	V	B	U	Telescope	CCD
2006 Sep 11	53990.213	14.04	-	16.11	17.19	-	1.3m	Phot
2006 Sep 12	53991.470	14.02	-	16.07	17.19	-	1.3m	Phot
2006 Sep 14	53992.522	14.08	-	16.21	17.31	-	1.3m	Phot
2006 Sep 14	53993.484	14.04	-	16.15	17.26	-	1.3m	Phot
2006 Sep 17	53995.527	14.06	-	16.18	17.34	-	1.3m	Phot
2006 Sep 18	53996.518	13.98	-	16.00	17.05	-	1.3m	Phot
2006 Sep 22	54001.321	14.07	15.26	16.19	17.34	17.10	1.3m	Phot
2006 Sep 23	54002.406	14.06	-	16.21	17.35	-	1.3m	Phot
2006 Sep 25	54004.388	14.03	-	16.10	17.21	-	1.3m	Phot
2006 Sep 26	54005.386	13.98	-	16.00	17.10	-	1.3m	Phot
2006 Sep 27	54006.312	14.02	15.18	16.08	17.17	-	1.3m	Phot
2006 Sep 29	54008.425	14.06	-	16.17	17.27	-	1.3m	Phot
2006 Sep 30	54009.186	14.05	15.22	16.13	17.25	17.07	1.3m	Phot
2006 Oct 05	54014.237	14.06	15.24	16.16	17.22	17.00	1.3m	Phot
2006 Oct 18	54027.473	13.97	15.06	16.09	-	-	Sch	ST-8
2006 Oct 19	54028.416	13.94	14.98	15.92	17.04	-	Sch	ST-8
2006 Oct 20	54029.392	13.93	15.01	15.91	17.02	-	Sch	ST-8
2006 Nov 17	54057.239	13.99	15.08	16.09	17.23	16.94	Sch	ST-8
2006 Nov 18	54058.254	14.00	15.11	16.12	17.40	17.18	Sch	ST-8
2006 Nov 19	54059.259	14.01	15.13	16.10	17.21	-	Sch	ST-8
2006 Nov 20	54060.202	13.98	15.07	16.07	17.27	17.01	Sch	ST-8
2006 Nov 21	54061.429	13.88	-	15.87	16.97	-	Sch	ST-8
2006 Dec 14	54084.193	14.07	15.11	16.10	17.23	16.96	2m	VA
2006 Dec 15	54085.244	14.06	15.13	16.09	17.20	16.96	2m	VA
2006 Dec 16	54086.247	13.93	15.02	15.98	17.10	-	Sch	ST-8
2007 Apr 09	54199.518	14.09	15.02	16.08	-	-	2m	VA
2007 Apr 09	54200.477	14.05	15.10	16.17	17.40	16.71	2m	VA
2007 Jun 26	54278.359	-	14.97	15.85	16.94	16.78	1.3m	Phot
2007 Jun 30	54282.347	13.96	15.07	15.98	17.09	-	1.3m	Phot
2007 Jul 01	54283.462	13.98	15.12	16.02	17.14	16.93	1.3m	Phot
2007 Jul 02	54284.310	13.94	-	15.94	17.05	-	1.3m	Phot
2007 Jul 03	54285.424	14.02	15.20	16.15	17.25	16.99	1.3m	Phot
2007 Jul 18	54300.446	13.93	-	15.93	17.06	-	1.3m	ANDOR
2007 Jul 20	54301.546	13.93	-	15.95	17.07	-	1.3m	ANDOR
2007 Jul 23	54305.439	13.90	14.98	15.87	17.02	16.66	1.3m	ANDOR
2007 Jul 24	54306.458	13.93	15.05	15.92	17.03	16.68	1.3m	ANDOR
2007 Aug 02	54314.557	14.03	-	16.12	17.30	-	1.3m	ANDOR
2007 Aug 14	54327.283	14.08	15.12	16.14	17.25	17.30	2m	VA
2007 Aug 15	54328.290	14.03	15.06	16.05	17.21	-	2m	VA
2007 Aug 16	54329.314	14.07	15.11	16.08	17.17	16.76	2m	VA
2007 Aug 17	54330.423	13.99	14.97	15.98	17.09	16.82	2m	VA
2007 Aug 18	54331.340	13.89	15.01	15.85	16.90	-	Sch	ST-8
2007 Aug 19	54332.330	13.87	14.98	15.85	16.91	-	Sch	ST-8
2007 Aug 20	54333.340	13.94	15.07	16.01	17.07	-	Sch	ST-8
2007 Sep 10	54354.495	13.91	15.06	15.92	17.02	-	Sch	ST-8
2007 Sep 14	54357.511	13.89	15.03	-	-	-	Sch	ST-8
2007 Nov 06	54411.260	14.04	-	16.03	17.12	-	2m	VA
2007 Nov 08	54413.291	13.99	14.98	15.97	17.06	-	2m	VA
2008 Mar 01	54526.672	14.07	15.13	16.12	17.22	-	Sch	STL-11000M
2008 Jun 28	54646.358	13.98	15.10	16.03	17.14	-	1.3-m	ANDOR
2008 Jun 29	54647.339	14.01	15.16	16.11	17.22	-	1.3-m	ANDOR
2008 Jul 06	54654.348	14.11	15.31	16.25	17.40	-	1.3m	ANDOR
2008 Jul 08	54656.426	14.00	-	16.13	17.18	-	1.3m	ANDOR
2008 Jul 13	54661.383	14.08	15.27	16.27	17.44	17.08	1.3m	ANDOR
2008 Jul 24	54672.367	14.12	15.32	16.30	17.44	17.18	1.3m	ANDOR
2008 Jul 25	54673.377	14.08	15.28	16.28	17.43	17.17	1.3m	ANDOR
2008 Aug 02	54680.544	14.00	-	16.12	17.26	-	1.3m	ANDOR
2008 Aug 27	54706.334	14.08	15.10	16.09	17.26	-	Sch	STL-11000M

Table 1: *continued.*

Date	JD (24...)	I	R	V	B	U	Telescope	CCD
2008 Aug 28	54707.374	14.14	15.21	16.20	17.29	-	Sch	STL-11000M
2008 Oct 21	54761.236	14.04	15.12	16.03	17.02	-	Sch	STL-11000M
2008 Oct 23	54763.229	14.04	15.16	16.02	-	-	Sch	STL-11000M
2008 Nov 20	54791.173	14.08	15.14	16.04	17.09	-	Sch	STL-11000M
2008 Dec 26	54827.342	13.98	-	16.14	-	-	2m	VA
2009 Jan 10	54842.212	14.12	15.31	16.30	17.54	-	Sch	STL-11000M
2009 Jan 12	54844.256	14.15	15.32	16.29	17.38	-	Sch	STL-11000M
2009 Mar 24	54915.407	14.02	15.18	16.20	17.30	-	Sch	STL-11000M
2009 Mar 26	54917.497	14.07	15.28	16.19	17.35	-	Sch	STL-11000M
2009 Apr 16	54938.435	14.10	15.31	16.23	17.29	-	Sch	STL-11000M
2009 May 19	54971.420	13.97	15.13	16.00	17.01	-	Sch	STL-11000M
2009 Jun 12	54994.504	13.95	15.11	16.09	17.21	16.76	1.3m	ANDOR
2009 Jun 18	55000.545	13.99	-	16.12	17.19	-	1.3m	ANDOR
2009 Jun 21	55003.502	14.04	15.23	16.22	17.28	16.93	1.3m	ANDOR
2009 Jun 24	55006.500	13.96	15.12	16.05	17.10	-	1.3m	ANDOR
2009 Jun 29	55011.527	14.08	15.34	16.34	17.39	-	Sch	FLI
2009 Jul 02	55014.531	14.22	-	16.67	17.85	-	1.3m	ANDOR
2009 Jul 07	55019.530	14.15	15.44	16.44	17.60	-	1.3m	ANDOR
2009 Jul 10	55022.535	14.16	-	16.51	17.67	-	1.3m	ANDOR
2009 Jul 14	55027.440	14.13	15.48	16.42	17.51	-	Sch	FLI
2009 Jul 15	55028.462	14.18	15.64	16.53	17.88	-	Sch	FLI
2009 Jul 16	55029.469	14.14	15.41	16.35	17.56	-	Sch	FLI
2009 Jul 19	55031.517	14.02	-	16.23	17.32	-	1.3m	ANDOR
2009 Jul 25	55037.503	14.11	15.34	16.35	17.44	17.24	1.3m	ANDOR
2009 Jul 27	55040.440	14.14	-	16.47	-	-	1.3m	ANDOR
2009 Jul 28	55041.273	14.12	15.37	16.36	17.46	17.05	1.3m	ANDOR
2009 Jul 31	55044.390	14.13	15.37	16.37	17.51	17.16	1.3m	ANDOR
2009 Aug 21	55065.354	14.33	15.73	16.89	18.10	-	Sch	FLI
2009 Aug 22	55066.284	14.29	15.65	16.68	17.86	-	Sch	FLI
2009 Oct 07	55112.379	14.24	15.62	16.58	17.55	-	Sch	FLI
2009 Oct 08	55113.354	14.21	15.55	16.54	17.65	-	Sch	FLI
2009 Oct 09	55114.246	14.23	15.58	16.53	17.73	-	Sch	FLI
2009 Nov 20	55156.238	14.19	15.52	16.52	17.61	-	Sch	FLI
2009 Nov 21	55157.267	14.17	15.55	16.55	17.62	-	Sch	FLI
2009 Nov 25	55161.239	14.31	15.44	16.50	17.67	17.18	2m	VA
2010 Mar 12	55268.553	14.18	15.22	16.26	17.42	-	2m	VA
2010 May 13	55330.374	14.00	15.23	16.19	17.35	-	Sch	FLI
2010 Jun 08	55356.418	14.03	15.27	16.16	17.36	-	Sch	FLI
2010 Jun 10	55358.468	14.07	15.39	16.37	17.55	-	Sch	FLI
2010 Jun 12	55359.508	14.12	15.46	16.37	17.46	-	Sch	FLI
2010 Jun 12	55360.442	14.09	15.43	16.41	17.40	-	Sch	FLI
2010 Jul 13	55391.395	14.13	15.26	16.34	17.38	17.26	2m	VA
2010 Jul 18	55396.339	14.10	15.29	16.40	17.32	17.22	2m	VA
2010 Aug 04	55413.309	14.04	15.36	16.26	17.42	-	Sch	FLI
2010 Aug 06	55415.397	14.03	15.31	16.23	17.34	-	Sch	FLI
2010 Aug 07	55416.360	14.03	15.18	16.11	17.13	-	Sch	FLI
2010 Aug 11	55420.318	14.03	15.30	16.24	17.37	17.16	1.3m	ANDOR
2010 Aug 12	55421.418	14.00	15.25	16.17	17.31	-	1.3m	ANDOR
2010 Aug 24	55433.490	13.88	15.03	15.94	16.93	-	1.3m	ANDOR
2010 Aug 25	55434.336	13.90	15.08	15.94	16.94	16.84	1.3m	ANDOR
2010 Aug 26	55435.370	13.92	15.10	15.99	17.03	16.84	1.3m	ANDOR
2010 Sep 08	55447.520	14.09	15.41	16.22	17.48	-	Sch	FLI
2010 Sep 08	55448.435	14.05	15.30	16.25	17.26	-	Sch	FLI
2010 Sep 09	55449.480	14.12	15.45	16.44	17.50	-	Sch	FLI
2010 Oct 11	55481.452	13.86	15.14	16.07	17.04	-	1.3m	ANDOR
2010 Oct 29	55499.326	13.96	15.06	16.06	17.15	16.81	2m	VA
2010 Oct 30	55500.301	14.07	15.17	16.18	17.31	16.51	2m	VA
2010 Nov 01	55502.276	14.06	15.19	16.21	17.34	17.07	2m	VA

Table 1: *continued.*

Date	JD (24...)	I	R	V	B	U	Telescope	CCD
2010 Nov 04	55505.298	14.06	15.36	16.34	17.39	-	Sch	FLI
2010 Nov 05	55506.313	14.08	15.41	16.39	17.41	-	Sch	FLI
2011 Jan 01	55563.256	14.10	15.43	16.39	17.52	-	Sch	FLI
2011 Jan 06	55568.234	14.04	15.15	16.17	17.31	-	2m	VA
2011 Jan 09	55571.275	14.08	15.25	16.34	17.54	-	2m	VA
2011 Feb 06	55599.228	13.98	15.25	16.15	17.33	-	Sch	FLI
2011 Apr 04	55656.422	14.02	15.13	16.16	17.16	-	Sch	FLI
2011 May 22	55704.392	14.00	15.32	16.23	17.39	-	Sch	FLI
2011 May 23	55705.335	14.07	15.39	16.39	17.58	-	Sch	FLI
2011 May 24	55706.324	14.04	15.37	16.34	17.57	-	Sch	FLI
2011 May 25	55707.335	13.91	15.16	16.09	17.19	-	Sch	FLI
2011 Jun 09	55722.354	13.90	15.05	15.95	16.96	-	Sch	FLI
2011 Jun 21	55734.470	14.02	15.38	16.32	17.35	-	Sch	FLI
2011 Jun 24	55737.404	13.99	15.21	16.17	17.29	-	Sch	FLI
2011 Jul 27	55770.412	13.99	15.31	16.24	17.34	-	Sch	FLI
2011 Aug 18	55791.563	13.88	-	15.95	17.03	-	1.3m	ANDOR
2011 Aug 23	55797.366	13.95	15.22	16.16	17.22	-	Sch	FLI
2011 Aug 24	55798.390	13.96	15.21	16.09	17.14	-	Sch	FLI
2011 Aug 25	55799.392	13.94	15.21	16.10	17.14	-	Sch	FLI
2011 Sep 10	55815.290	13.89	15.06	15.99	17.03	16.77	1.3m	ANDOR
2011 Sep 11	55816.444	13.89	15.05	15.95	17.01	-	1.3m	ANDOR
2011 Sep 19	55824.310	13.97	15.18	16.17	17.24	-	1.3m	ANDOR
2011 Sep 23	55828.302	13.94	15.17	16.03	17.16	-	Sch	FLI
2011 Oct 13	55848.318	13.94	15.14	16.09	17.21	-	1.3m	ANDOR
2011 Oct 30	55865.280	14.14	15.15	16.12	17.24	-	2m	VA
2011 Nov 29	55895.296	14.01	15.26	16.19	17.24	-	Sch	FLI
2011 Nov 30	55896.277	14.00	15.27	16.20	17.23	-	Sch	FLI
2011 Dec 29	55925.222	13.97	15.14	16.05	17.06	-	Sch	FLI
2012 Jan 30	55957.221	13.97	15.17	16.20	-	-	2m	VA
2012 Mar 16	56003.488	14.03	15.25	16.18	17.32	-	Sch	FLI
2012 Apr 12	56030.484	14.08	15.36	16.30	17.43	-	Sch	FLI
2012 Jun 12	56091.443	14.07	15.34	16.26	17.40	-	Sch	FLI
2012 Jun 18	56096.522	14.07	15.36	16.29	17.41	-	Sch	FLI
2012 Jul 11	56120.447	14.11	15.41	16.29	17.34	-	Sch	FLI
2012 Jul 13	56122.443	14.13	15.44	16.35	17.51	-	Sch	FLI
2012 Jul 14	56123.438	14.15	15.48	16.40	17.60	-	Sch	FLI
2012 Aug 01	56141.439	14.11	15.37	16.34	17.47	-	1.3m	ANDOR
2012 Aug 19	56159.393	14.07	15.37	16.20	17.31	-	Sch	FLI
2012 Aug 20	56160.398	14.10	15.39	16.26	17.40	-	Sch	FLI
2012 Aug 21	56161.453	14.07	15.34	16.17	17.23	-	Sch	FLI
2012 Aug 22	56162.378	14.08	15.35	16.26	17.33	-	Sch	FLI
2012 Sep 02	56173.374	14.07	15.29	16.25	17.35	17.16	1.3m	ANDOR
2012 Sep 11	56182.290	14.09	15.34	16.31	17.44	17.21	1.3m	ANDOR
2012 Sep 23	56194.364	14.08	15.37	16.27	17.36	-	Sch	FLI
2012 Oct 09	56210.265	14.11	15.41	16.31	17.40	-	Sch	FLI
2012 Nov 18	56250.355	14.04	15.32	16.24	17.33	-	Sch	FLI
2012 Dec 14	56276.305	14.03	15.16	16.18	17.30	-	2m	VA
2013 Feb 04	56328.241	13.99	15.23	16.09	17.16	-	Sch	FLI
2013 Mar 17	56369.516	14.18	15.14	16.18	17.38	-	2m	VA
2013 Apr 11	56394.389	13.98	15.20	16.14	17.13	-	Sch	FLI
2013 May 02	56415.490	13.94	15.18	16.07	17.12	-	Sch	FLI
2013 May 30	56443.497	13.90	15.12	16.01	16.93	-	Sch	FLI
2013 May 31	56444.481	14.03	15.29	16.18	17.24	-	Sch	FLI
2013 Jul 04	56478.438	13.97	14.90	15.85	16.98	-	2m	VA
2013 Aug 02	56507.444	14.09	15.13	16.18	17.32	-	2m	VA
2013 Aug 04	56509.368	14.04	15.32	16.20	17.33	-	Sch	FLI
2013 Aug 05	56510.452	13.95	15.11	16.02	17.16	-	60cm	FLI
2013 Aug 06	56511.493	13.97	15.19	16.23	17.61	-	60cm	FLI

Table 1: *continued.*

Date	JD (24...)	I	R	V	B	U	Telescope	CCD
2013 Aug 07	56512.481	14.01	15.24	16.13	17.55	-	60cm	FLI
2013 Aug 08	56513.469	13.94	15.16	16.05	17.21	-	60cm	FLI
2013 Aug 09	56514.427	14.05	15.21	16.10	17.30	-	60cm	FLI
2013 Sep 04	56540.376	14.03	15.33	16.25	17.41	-	Sch	FLI
2013 Sep 06	56542.440	14.01	15.24	16.14	17.29	-	Sch	FLI
2013 Sep 08	56544.406	14.06	15.02	16.04	17.16	-	2m	VA
2013 Sep 11	56547.471	14.01	15.20	16.13	17.33	-	60cm	FLI
2013 Sep 14	56550.302	14.08	15.33	16.30	17.30	-	60cm	FLI
2013 Sep 17	56553.364	14.00	15.26	16.20	17.35	-	1.3m	ANDOR
2013 Oct 11	56577.445	13.98	15.25	16.17	17.08	-	60cm	FLI
2013 Oct 12	56578.461	14.02	15.34	16.18	17.40	-	60cm	FLI
2013 Nov 07	56604.423	13.91	15.12	15.99	17.15	-	60cm	FLI
2013 Dec 29	56656.307	14.00	15.25	16.17	17.28	-	Sch	FLI
2014 Jan 23	56681.282	13.95	15.08	16.02	17.17	-	Sch	FLI
2014 Feb 05	56694.593	14.05	15.08	16.08	17.26	-	2m	VA